PATENT SPECIFICATION

DRAWINGS ATTACHED

885,151

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COMPLETE SPECIFICATION

Improvements in or relating to Anamorphic Optical Systems

I, JAN LOUIS WULFF JACOBSEN, a Norwegian Subject of c/o Arnold & Richter K.G., Trükenstrasse 89, Müchen 13, Germany, do hereby declare the invention, for which I pray that a Patent may be granted to me, and the method by which it is performed, to be particularly described in and by the following statement:—

This invention concerns anamorphic optical systems such as used for the taking and projecting of motion pictures to create on the screen an image which has a width to height ("aspect") ratio greater than that of the film frame. In the taking of such pictures an anamorphic optical system is used to "compress" the scene in a horizontal direction so as to produce a film image, of a scene of greater than standard aspect ratio, that fits a film frame of standard aspect ratio whilst during subsequent projection the horizontally "compressed" film image is horizontally "expanded" by an anamorphic optical projection system to produce a screen image having the proportions of the original scene. Thus, for example, if a scene being taken with an anamorphic optical system includes a circle the film image of that circle will be an ellipse with a vertical major axis whilst projection of that film image with an appropriate anamorphic optical system will result in a screen image in which the ellipse of the film image appears as a circle on the screen.

Prior art anamorphic optical systems used in the above described manner suffer from the defect that objectionable "barrel" distortion is produced by the taking system, especially when the system is of short focal length. Conversely, the projection system produces some "pincushion" distortion and whilst this can effect some compensation for the "barrel" distortion of the film image, the results are acceptable only if the "barrel" distortion of the film image is maintained within fairly close, low value limits. In practice, therefore, acceptable results are achieved only if the taking system has a focal length greater than a certain minimum value.

An object of the present invention is to provide an anamorphic optical system in which image distortion (other than pure compression or expansion) is minimised and which is especially suitable for working at short focal lengths.

An anamorphic optical system in accordance with the present invention comprises an objective in combination with an afocal anamorphic lens system including a first anamorphoser adapted to produce an image-compression in a first direction and a second anamorphoser adapted to produce an image-expansion in a second direction at right-angles to said first direction, the image-compression factor in said first direction and the image-expansion factor in said second direction having a quotient equal to the desired anamorphic factor of the system.

In such an anamorphic optical system, distortion is reduced, in comparison with prior art systems of the same anamorphic factor, for two reasons: first, the "barrel" distortion produced by the first anamorphoser of the system is at least partially compensated by the "pin-cushion" distortion produced by the second anamorphoser; secondly, the two anamorphosers have individual anamorphic factors numerically less than the anamorphic factor of the system as a whole whereby their individual distortions can be made less than that of a single anamorphoser having the desired anamorphic factor of the system as a whole.

Additionally, focusing adjustment of the system of the invention does not unacceptably alter the anamorphic factor of the system as a whole, even when focusing on close objects.

It will be understood that, because of the image "expansion" produced by the second anamorphoser, an anamorphic optical system in accordance with the invention has, effectively, a greater focal length than that of the objective of the system; however, since the system produces acceptably low distortion when working at short focal lengths a desired system focal length can be obtained by the

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use of an objective of appropriately shorter focal length than the desired system focal length without excessive distortion arising. For instance, whereas prior art taking systems having an anamorphic (compression) factor of 2 are in practice limited to working at focal lengths not less than about 50 mm., an anamorphic taking system in accordance with the invention can, with the same anamorphic factor, have an effective focal length of 40 mm. by the use of an objective of 35 mm. focal length without unacceptable distortion of the image.

In an anamorphic optical system in accordance with the invention, the first anamorphoser may comprise, fundamentally, a pair of spaced-apart cylindrical lens components having parallel cylinder axes at right-angles to the said first direction, one of these lens components being of positive power and the other of negative power whilst the second anamorphoser may comprise, fundamentally, a pair of spaced apart cylindrical lens components, one of negative power and the other of positive power, having their cylinder axes at right-angles to the said second direction. However, to facilitate focusing adjustments of the system and to avoid or minimise changes in anamorphic factor upon focusing adjustment, the negative lens component of the first anamorphoser may be constituted by two spaced-apart negative cylindrical lenses, the rear negative components of the two anamorphosers having an equal power and therefore being adapted for common focusing adjustment. Such common focusing adjustment will have little effect upon the anamorphic factor of the system as a whole since such adjustment tends to alter the anamorphic factors of the two anamorphosers in complementary manner.

To facilitate manufacture of the system and the provision of such common focusing adjustment of the said negative lens components of the two anamorphosers, and also to eliminate a pair of glass surfaces in the system, the two negative lens components concerned may, with appropriate design of the remainder of the anamorphic system, be arranged to be situated at a common point on the optical axis of the system, whereby they may be constituted by a single pherical lens component equivalent to a coalescence of the two negative cylindrical lens components.

To achromatise the anamorphic lens system it may be found advantageous to employ achromatic lenses for the rear lens components of the two anamorphosers only and to achieve achromatism of the other lens components in the system by inclusion of an afocal achromatising doublet consisting of a cemented pair of cylindrical lenses of different dispersion and having their cylinder axes at right-angles to one another and aligned with the said first and second directions.

Thus, for instance, in one form of the invention, an anamorphic optical system comprises four components in front of the objective of the system, the rearmost of said components being a positive, chromatically-corrected cylindrical doublet, constituting the rear positive component of the first anamorphoser, the second said component being a negative, chromatically-corrected spherical meniscus doublet adjustable along the optical axis and constituting a coalescence of the rear negative cylindrical components of the two anamorphosers, the third said component being an afocal cemented achromatising doublet of two elements of different dispersion, the rear element having a concave cylindrical rear surface with its cylinder axis aligned with said first direction and a convex cylindrical front surface with its cylinder axis aligned with said second direction while the front element of such doublet has a convex spherical surface, and the fourth component constituting the front negative component of the first anamorphoser and having a concave cylindrical rear surface with its cylinder axis aligned with said second direction and a convex spherical front surface which also constitutes the positive component of the second anamorphoser.

In another form of the invention, an anamorphic optical system comprises five components in front of the objective of the system, the rearmost of said components being a positive, chromatically-corrected cylindrical doublet constituting the rear positive component of the first anamorphoser, the second said component being a negative, chromatically-corrected, rearwardly concave, spherical meniscus doublet adjustable along the optical axis and constituting a coalescence of the rear negative cylindrical components of the two anamorphosers, the third said component being an afocal cemented achromatising doublet of two elements of different dispersion, the rear element having a concave cylindrical rear surface with its cylinder axis aligned with said first direction and a convex cylindrical front surface with its cylinder axis aligned with said second direction while the front element of such doublet has a convex spherical surface, the fourth said component constituting the front positive component of the second anamorphoser and having a convex spherical rear surface and a convex cylindrical front surface with its cylinder axis aligned with said first direction, and the fifth said component constituting the front negative component of the first anamorphoser and having a concave cylindrical rear surface with its cylinder axis aligned with said second direction and a convex spherical front surface.

In order that this invention may be more readily understood, certain embodiments of the same will now be described with reference to the accompanying drawings, in which:—

Figures 1 and 2 show in cross-section, a

diagrammatic representation of an anamorphic optical system according to the invention, the individual groups of lenses being represented separately;

Figures 3 and 4 show another embodiment of the invention, represented in the same way as in Figures 1 and 2;

Figure 5 shows a further embodiment of the invention in cross-section; and

Figures 6 and 7 show the embodiment of Figure 5 in two cross-sections at right angles to each other, but with achromatic lenses and additional curvature for the elimination of picture errors.

The drawings illustrate the invention only diagrammatically. The mounts for supporting the lenses and groups of lenses are not shown and nor are the means for adjusting the focussing lenses in relation to the objective of the system by displacement in the direction of the principal optical axis of the system. Such mounts and moving mechanisms are known and are used as appropriate in the system according to the invention.

In the drawings, O denotes the objective of the system. The line beneath the objective in Figures 1 to 5 or on the right of the objective in Figures 6 and 7 denotes the focal plane of the system.

Figure 1 represents the known arrangement of an objective O in front of which is located an anamorphoser for producing image-compression in the plane of the paper, for instance in the horizontal direction, this anamorphoser being constituted by a negative front lens 1 and a positive back lens 2 both having cylindrical surfaces with cylinder axes perpendicular to the plane of the paper. Figure 2 shows the arrangement of an objective O in front of which is located an anamorphoser for producing image-expansion in a direction perpendicular to the plane of the paper, the anamorphoser being constituted by a positive front lens 3 and a negative back lens 4, these lenses having cylindrical surfaces with cylinder axes that are parallel to each other and in the plane of the paper, i.e. have been rotated, in comparison with a view of Figure 1, through 90° about the principal optical axis of the system.

If the anamorphoser (lenses 3 and 4) shown in Figure 2 is positioned between the two lenses 1, 2 of the arrangement shown in Figure 1, one embodiment of the invention is obtained. In such a system in accordance with the invention there is, therefore, in front of the objective O, an afocal anamorphic lens system of two anamorphoser lens groups 1, 2 and 3, 4 respectively whose axes of symmetry cross eath other at right angles, each group having two lenses with cylindrical surfaces the cylinder axes of which are parallel, one lens group (compressing group) constituting a first anamorphoser that produces a picture-compression in a first direction (e.g. horizontally) whilst the other lens group (expanding group) constitutes a second anamorphoser that produces a picture-expansion in a second direction at right angles to the first direction, e.g. vertically.

In Figure 3, an arrangement is illustrated that is similar to that shown in Figure 1 but with the difference that the front negative lens 1 of the arrangement of Figure 1 is divided into two negative cylindrical lenses 5 and 6, the cylinder axes of which are parallel to each other. Figure 4 shows again the arrangement of Figure 2 and if the two lens systems of Figures 3 and 4 are combined as described for Figures 1 and 2 there is again produced an arrangement which has the same properties and gives the same effects, characteristic of the invention, which have been explained with the aid of Figures 1 and 2. However, the focussing is, in the case of this embodiment, effected by a common movement of the lenses 4 and 6 in the same direction, the lenses 4 and 6 having equal powers for this purpose. It should be mentioned that the distance between the cylindrical lenses 3 and 4 of the expanding group in Figure 4 may be made equal to the distance between the two negative cylindrical lenses 5 and 6 of the compressing group. The second negative cylindrical lens 6 is then arranged so as to be closely adjacent to the lens 4 to facilitate the provision of the common focussing adjustment for lenses 4 and 6.

Figure 5 illustrates a lens system according to the invention which corresponds substantially to the embodiment illustrated by Figures 3 and 4 combined as described above. However, in Figure 5, the two cylindrical lenses 4 and 6 have been replaced by a single spherical lens 7 that represents a coalescence of the two lenses when the system has been designed to have both lenses 4 and 6 at a common point along the optical axis; focussing is effected by displacing the lens 7.

Figures 6 and 7 show an arrangement according to Figure 5 but showing the use of achromatic lenses and additional curvature of certain lens surfaces for obviating image defects.

The leneses L_1, L_2, L_6, L_8 correspond to the lenses 5, 3, 7, 2 (Figure 5) chosen in the same order. The lenses L_3 and L_4 are the crown-glass and flint elements of a cemented doublet, the cylinder axes of element L_4 crossing each other at right angles, for achromatising the lenses L_1, L_2. The lenses L_5, L_7 are the achromatising lenses of the lenses L_6, L_8.

In Figure 6, it is indicated for every lens surface whether it is spherical or cylindrical; l_1, l_2 and so on denote the distances of the individual lenses from one another, d_1, d_2 and so on denote the lens thicknesses and R_1, R_2 and so on denote the radii of the lens surfaces.

By way of example the following Table shows for the individual lenses of an anamorphic optical system of a focal length of 40 mms., the values of the radii R, the refractive index, and the Abbe number as well as the values of the distances *l* and of the thicknesses *d*. The individual values given in the Table have been ascertained either mathematically, in accordance with known optical laws, or empirically.

Lens	Radii	Refractive Index (n)	Abbe Number	Distances (l)	Thicknesses (d)	Curvature
L_1	$R_1 = + 554$ $R_2 = + 67.5$	1.5225	59.64	$l_1 = 11.8$	$d_1 = 4$	+ sph + cyl
L_2	$R_3 = + 173$ $R_4 = - 1280$	1.5225	59.64	$l_2 = 9.1$	$d_2 = 6$	+ cyl – sph
L_3	$R_5 = + 332$ $R_6 = + 87.5$	1.5225	59.64		$d_3 = 5$	+ sph + cyl
L_4	$R_7 = + 245$	1.6200	36.34	$l_3 = 2.3$ to 23.5	$d_4 = 13.7$	+ cyl
L_5	$R_8 = + 68.5$ $R_9 = + 89$	1.6200	36.4		$d_5 = 3.2$	+ sph + sph
L_6	$R_{10} = + 39$	1.5567	58.54	$l_4 = 53.8$ to 26.1	$d_6 = 1.0$	+ sph
L_7	$R_{11} = - 245$ $R_{12} = + 174$	1.6200	36.34		$d_7 = 1.0$	– cyl + sph
L_8	$R_{13} = - 74$	1.5225	59.64		$d_8 = 2.5$	– cyl

WHAT I CLAIM IS:—

1. An anamorphic optical system comprising an objective in combination with an afocal anamorphic lens system including a first anamorphoser adapted to produce an image-compression in a first direction and a second anamorphoser adapted to produce an image-expansion in a second direction at right angles to said first direction, the image-compression factor in said first direction and the image-expansion factor in said second direction having a quotient equal to the desired anamorphic factor of the system.

2. An optical system according to claim 1, wherein said first anamorphoser comprises a rear positive cylindrical component and two spaced-apart negative cylindrical components whilst the second anamorphoser comprises a pair of spaced-apart cylindrical components, one of negative power and the other of positive power, the rear negative components of the two anamorphosers having an equal power and therefore being adapted for common focussing adjustment along the optical axis of the system.

3. An optical system according to claim 2, wherein the rear negative components of the two anamorphosers are arranged to be situated at a common point on the optical axis of the system and are constituted by a single spherical lens component.

4. An optical system according to claim 2 or 3, wherein the anamorphosers have achromatic rear lens components, the system including an afocal achromatising doublet consisting of a cemented pair of cylindrical lenses of different dispersion and having their cylinder axes at right angles to one another and aligned with said first and second directions to achromatise the other lens components of the system.

5. An optical system according to claims 3 and 4, comprising four components in front of the objective of the system, the rearmost of said components being a positive, chromatically-corrected cylindrical doublet, constituting the rear positive component of the first anamorphoser, the second said component being a negative chromatically-corrected spherical meniscus doublet adjustable along the optical axis and constituting a coalescence of the rear negative cylindrical components of the two anamorphosers, the third said com-

ponent being an afocal cemented achromatising doublet of two elements of different dispersion, the rear element having a concave cylindrical front surface with its cylinder axis aligned with said second direction while the front element of such doublet has a convex spherical surface, and the fourth component constituting the front negative component of the first anamorphoser and having a concave cylindrical rear surface with its cylinder axis aligned with said second direction and a convex spherical front surface which also constitutes the positive component of the second anamorphoser.

6. An optical system according to claims 3 and 4, comprising five components in front of the objective of the system, the rearmost of said components being a positive, chromatically-corrected cylindrical doublet constituting the rear positive component of the first anamorphoser, the second said component being a negative, chromatically-corrected, rearwardly concave, spherical meniscus doublet adjustable along the optical axis and constituting a coalescence of the rear negative cylindrical components of the two anamorphosers, the third said component being an afocal cemented achromatising doublet of two elements of different dispersion, the rear element having a concave cylindrical rear surface with its cylinder axis aligned with said first direction and a convex cylindrical front surface with its cylinder axis aligned with said second direction while the front element of such doublet has a convex spherical front surface, the fourth said component constituting the front positive component of the second anamorphoser and having a convex spherical rear surface and a convex cylindrical front surface with its cylinder axis aligned with said first direction, and the fifth said component constituting the front negative component of the first anamorphoser and having a concave cylindrical rear surface with its cylinder axis aligned with said second direction and a convex spherical front surface.

7. An anamorphic optical system substantially as described with reference to, and as shown in Figures 1 and 2 of the accompanying drawings.

8. An anamorphic optical system substantially as described with reference to, and as shown in, Figures 3 and 4 of the accompanying drawings.

9. An anamorphic optical system substantially as described with reference to, and as shown in Figure 5 of the accompanying drawings.

10. An anamorphic optical system substantially as described with reference to, and as shown in Figures 6 and 7 of the accompanying drawings.

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Fig. 1

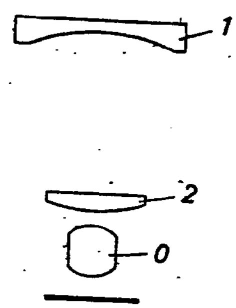


Fig. 2

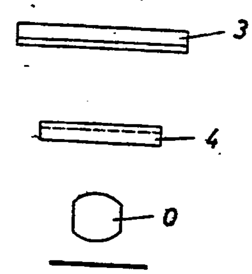


Fig. 3

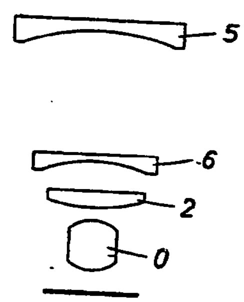


Fig. 4

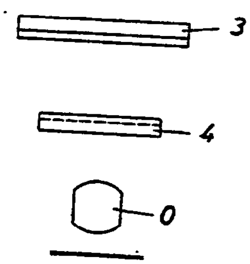
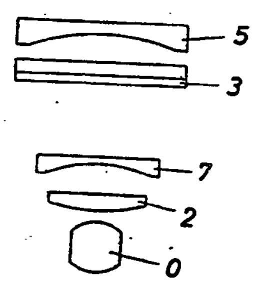


Fig. 5



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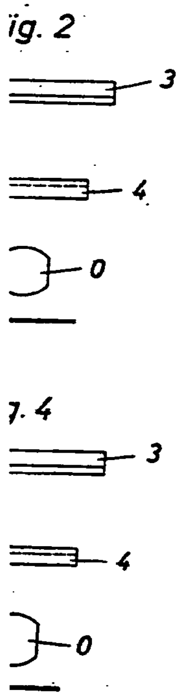
2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheets 1 & 2



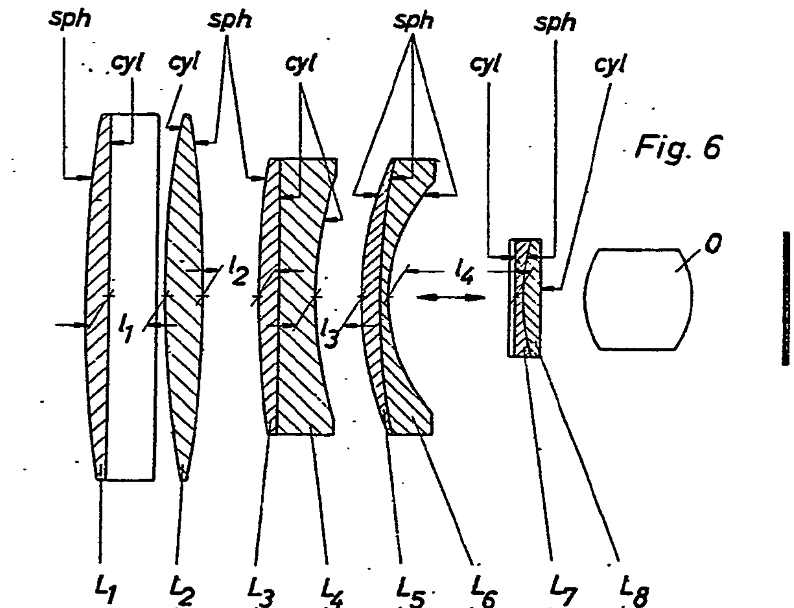


Fig. 6

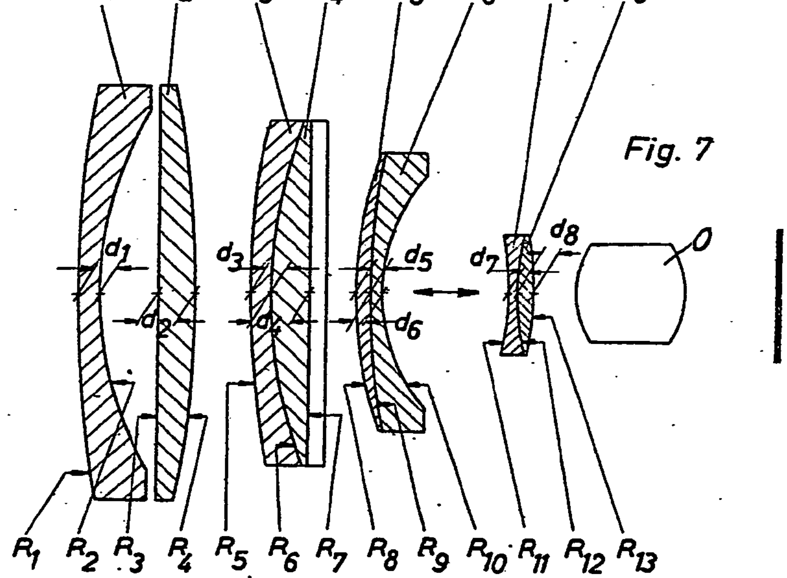


Fig. 7

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2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheets 1 & 2

Fig. 1

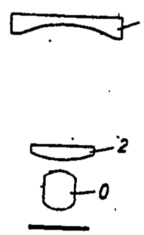

Fig. 2

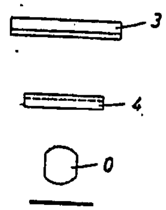

Fig. 3

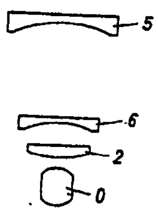

Fig. 4

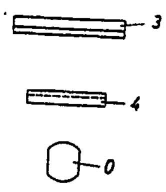

Fig. 5

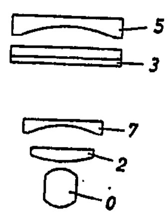

Fig. 6

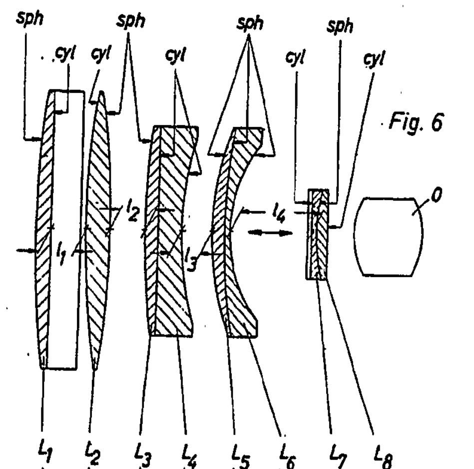

Fig. 7